PROCEEDINGS

OF THE

CALIFORNIA ACADEMY OF SCIENCES

FOURTH SERIES

VOL. XI, No. 1, pp. 1-26 JULY 6, 1921

I

NOTES ON A FAUNA OF THE VIGO GROUP AND ITS BEARING ON THE EVOLUTION OF MARINE MOLLUSCAN FAUNAS

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The rate of evolution of a marine invertebrate fauna in the tropics when compared with that of faunas of the temperate zones brings out some interesting results. During the past year, 1919-1920, the writer has had the opportunity and rare good fortune to collect some excellently preserved fossils from the Vigo group of the Philippine Islands incidental to some economic investigations in which he was engaged. After several years spent in study of the Tertiary faunal problems of the Pacific Coast of North America, the writer naturally had acquired to a certain extent a point of view of the worker in temperate climes. However, many interesting problems in the Eocene of California, Oregon, and Washington suggested that Eocene marine molluscan faunas did not evolve as rapidly as those of the Miocene and Pliocene and that the same "yardstick" in the Tertiary geological time scale could not be applied. Many problems of the Eocene are directly connected with the rate of evolution of a tropical fauna, and, as the Eocene faunas of California, Oregon, and Washington are essentially tropical or sub-tropical, the writer was glad to devote spare time to the study of a tropical fauna.

Does the Lyell percentage system apply to tropical invertebrate faunas? In answering this question one must bear in mind that this scale is really an expression of the time rate of evolution of Tertiary molluscan faunas based upon the study of the Tertiary of Europe. Briefly, this scale, as now generally applied, is: Eocene, 0%; Oligocene, 3%; Miocene, 25%; Pliocene, 60%; and Pleistocene, 90%. Practically all the Eocene molluscan genera exist today in the Recent faunas of the tropical and temperate zones. Great was our surprise to find that our collections from the upper Vigo shales and the Canguinsa formation, regarded by Pratt[1] and Smith as being of Lower Miocene and Oligocene age, yielded a molluscan fauna containing 75% Recent species. The results of these preliminary studies indicate, that a negative answer must be given to the rhetorical question asked above. An essential modification of the Lyell percentage scale seems necessary to the writer for the proper interpretation of the Tertiary faunas of the tropics. If this hypothesis be true, then evidently marine molluscan faunal changes take place with far less rapidity in the tropics than in the temperate zones. Now this conclusion is apparently in direct contradiction to the fact that the recent molluscan fauna of the Philippines is specifically far more numerous than a recent fauna from a temperate region. Hidalgo[2] reports 4300 to 4500 terrestrial, fluvial, and marine testaceous mollusca, and, of these, fully two-thirds are marine. This anomaly will be considered after the presentation of the data.

Professor K. Martin[3] in "Tertiarschichten auf Java" recognized in a general way that the percentage system of Deshayes (and Lyell) did not strictly apply in Java and that climatic variation was a prime cause of this difference.

Brief Statement of Geological History

The fauna upon which this paper is based was collected from the southern half of the Bondoc Peninsula from strata referred

[1] Pratt, W. E., and Smith, W. D., "The Geology and Petroleum Resources of the Southern Part of Bondoc Peninsula," Tayabas Province, P. I., Phil. Jour. Sci., Vol. VIII, 1913, Sec. A, No. 5, p. 312.

[2] Hidalgo, J. G., Catalogo de los Moluscos Testaceous de las Islas Filipinas, Jolo y Marianas, p. 389, Madrid, 1904-1905.

[3] Martin, K., Die Tertiarschichten auf Java, p. 22-24, Die Lagerunas vethaeltnisse, Leiden, 1880.

by Pratt and Smith to the Canguinsa formation and Vigo group. In order that the reader may appreciate the significance of this assemblage of mollusca, a brief resumé of the geologic history of this region is necessary. The southern half of the Bondoc Peninsula consists almost entirely of marine sedimentary rocks which have been highly folded and faulted. The oldest rocks here recognized consist of shales and sandstones 3000 to 4000 feet in thickness, the Vigo group and its uppermost member, the Canguinsa formation. The strata as exposed in the vicinity of the Vigo River are steeply dipping, black, organic shales, subordinate sandstones, and minor lignitic strata which are unconformably overlain by the Malumbang formation.*

The Malumbang formation, consisting of coralline limestone and associated marls, varies in thickness from small residuals to 1000 feet. From what is known of the rate of growth of reef corals this formation must represent a long time interval. In a few places in the Bondoc Peninsula—notably in the vicinity of San Andreas—marine terraces truncate the Malumbang strata. These terraces are in places thickly mantled with coralline limestone of Pleistocene age. Some of the limestone four miles east of Mulanay at an elevation of 500 feet may represent high Pleistocene terraces, as terraces at this height occur in Leyte and at much greater elevations in Cebu where the same geological horizons are also found.

These horizons exhibit in northwest Leyte the same essential conditions and are beautifully exemplified in the vicinity of Toledo, Cebu, as well. The Vigo group in all probability occurs in the region north of Fort Pickett in Mindanao so that we are not dealing with local conditions but with general ones which existed over the site of these islands. The conditions of deposition during Malumbang and Pleistocene time resemble those existing today in the vicinity of the Bondoc Peninsula and essentially the same mollusca occur in the coral reef facies of all three. The deposition during Vigo time was in marked contrast with these later times in that the contributing land masses consisted largely of diorites, schists, and serpentines or

*Note.—The writer's view concerning the stratigraphy of this region differs in this regard from that of Pratt and Smith, but a full discussion of this important point can not be made here.

peridotites from which they were probably derived. At times the material contained in the Vigo sandstones is very coarse, and conglomerates occur locally in the Bondoc Peninsula and on a great scale in northwest Leyte, east of the barrio of Tababunga, where they in part resemble characteristic desert conglomerates closely. Such materials could not have been transported great distances and it is probable that a land mass or masses lay to the east of the site of the Bondoc Peninsula and northwestern Leyte. In other words the sediments of the Vigo group were deposited in the moderately deep waters of an inland sea with high mountainous islands to the east. The total time represented since the beginning of the Vigo is evidently long, and, on these grounds as well as faunal, the Vigo group appears to be as old as the Miocene, and the Malumbang probably represents at least a portion of the Pliocene. The time represented by the unconformity between these horizons was sufficiently long to reduce many of the mountains formed at the close of Vigo time to nearly base level before the region was again gradually lowered to receive its great load of Malumbang coralline limestone and associated marls in the clear, warm, shallow waters of a tropical Pliocene sea. Likewise the orogenic movements which ended Malumbang time and the erosion interval which preceded the formation of Pleistocene terraces were not brief. The age of the Vigo group will be discussed at length after its fauna is considered.

Fauna

The fauna upon which this paper is based was obtained from the Bahay River vicinity (2X, 3X, 4X, 5X); the canyon of Dumalog Creek (9X); and from Sapa Tubigbinukot, the northern extension of the Amoguis (Amougis), Agipot, Pagsanhan* River (11X), from strata which are all unmistakably members of the Vigo group and unconformably below the Malumbang formation.

The following notes upon the collection localities and their fossils are given in detail as there are but few places in these beautiful islands where good collections are obtained from

* Different local names for same stream.

localities with satisfactory stratigraphy. "Locality 2 X, Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west shore of Ragay Gulf, 600 meters up stream from Bureau of Lands Benchmark No. 1 (Bahay Oil Co., Well No. 1), on N. E. bank of Bahay River in a 50-foot cliff of yellow sandstone and bluish clayey sandstone disturbed by minor faulting. Coll. Roy E. Dickerson."

The Malumbang limestone is found in the hill 100 yards to the northeast, and from the general relations in the field it is clearly unconformable upon the underlying Canguinsa formation. The following fauna was obtained from this locality:

Locality 2 x

Actæon.
Architectonica pictum (Philippi); living.
Bullaria.
Cancellaria crenifera Sowerby; living.
Cerithium herklotsi K. Martin.
Cerithium jenkinsi K. Martin.
Cerithium monoliferum Kiener; living.
Conus ornatissimus K. Martin.
Conus, new species??
Conus lividus Hwass; living.
Conus, sp.
Cyclonassa.
Drillia.
Haminea.
Mitra javana K. Martin.
Mitra cf. jenkinsi K. Martin.
Mitra junghuhni K. Martin.
Nyctilochus.
Mangilia.
Nassa crenulata; living.
Nassa dispar Adams; living.
Nassa gemmulata (Lamarck); living.
Nassa globosa minor; living.
Nassa immersa Carpenter; living.
Nassa quadrasi Hidalgo; living.

Nassa thersites, variety; living.
Natica albumen Lamarck; living.
Natica.
Natica spadicea Reeve; living.
Natica mamilla Lamarck; living.
Nerita funiculata Reeve; living.
Olivella.
Ranella subgranulosa Beck; living.
Ranella.
Ranella tuberculata Broderip; living.
Strombus canarium Linnæus; living.
Strombus swainsoni Reeve; living.
Turris (Surcula) flavidus Lamarck; living.
Turris garnonsi Reeve; living.
Turris deshayesi (Doumet); living.
Turris carinata woodwardi K. Martin; living.
Terebra.
Terebra bicincta K. Martin.
Terebra javana K. Martin.
Arca cornea Reeve; living.
Cardium.
Corbula socialis K. Martin.
Corbula.
Chione chlorotica.
Ostrea.
Pleuronectia pleuronecta Linnæus; living.
Placuna placenta; living.
Psammobia cf. lessoni Blainville.
Pinna.
Solen.
Tellina.
Dentalium.
Coral.
Coral.
Echinoid.

The predominance of littoral species and the character of the strata indicate that these forms lived in the shallow inshore waters of an inland sea.

"Locality 3x, Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west shore of Ragay Gulf, Bahay River, up stream 800 meters from Bureau of Lands Benchmark No. 1 (Bahay Oil Co., Well No. 1), on southwest bank of stream in a stiff, dark gray shale. 8/25/19. Colls. Roy E. Dickerson and Mark Fuken. The following species were collected here:

Locality 3x

Actæon, species.
Architectonica pictum (Philippi); living.
Cancellaria elegans Sowerby; living.
Cerithium herklotsi K. Martin.
Cerithium monoliferum Kiener; living.
Cerithium jenkinsi K. Martin.
Cerithidea (Pyrazus) cf. sulcatus Brugiere; living.
Columbella bandongensis K. Martin.
Cypræa cf. tigris Linnæus; living.
Conus, new species?
Conus, species.
Conus ornatissimus K. Martin.
Distortio clathrata Lamarck; living.
Melania asperata; living.
Nassa thersites leptospira (Brugiere); living.
Nassa thersites immersa Carpenter; living.
Nassa quadrasi Hidalgo; living.
Nassa globosa minor Quoy; living.
Nassa crenulata (Brugiere); living.
Nassa canaliculata Lamarack; living.
Nassa dispar Adams; living.
Natica mamilla Lamarck; living.
Natica lacernula d'Orbigny; living.
Melania cf. asperata inquinata Quadras; living.
Mitra junghuhni K. Martin.
Mitra javana K. Martin.
Murex endivia Lamarck; living.
Olivella.
Phos.
Ranella tuberculata Broderip; living.
Rostellaria ficus; living.

Rostellaria crispata; living.
Strombus canarium; living.
Strombus, species a.
Strombus, species b.
Telescopium telescopium Linnæus; living.
Terebra.
Triton pfeifferianum Reeve; living.
Trivia.
Turris garnonsi Reeve; living.
Turris flavidula (Lamarck); living.
Turris deshayesi Doumet; living.
Turris carinata woodwardi K. Martin.
Turris coronifer K. Martin.
Vicarya callosa (?) Jenkins.
Arca ferruginea Reeve; living.
Arca granosa Linnæus; living.
Arca cornea Reeve; living.
Barbatia fusca (Brugiere); living.
Chione chlorotica Philippi; living.
Corbula socialis K. Martin.
Corbula.
Dosinia cf. lenticularis; living.
Placuna placenta; living.
Psammobia, species; living.
Paphia textrix Deshayes; living.
Ostrea.
Spisula, species.
Tellina, species.
Coral.
Coral.

This fauna flourished in slightly deeper water, or at least quieter water, as one specimen of the fragile *Placuna placenta* with both valves splendidly preserved shows that the specimen was not within strong wave action. The preservation of the other species is remarkably fine. The strata at this locality are nearly vertical, a good dip and strike being obtainable in the middle of the stream.

The following species were obtained from "Locality 4x, Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf, Bahay River, 320 meters east of mouth of Apad Creek, in road cut 60 feet above the river in yellow sandstone about 50 feet stratigraphically above the brackish-water fauna in the lignitic strata of Locality 5. Colls. Roy E. Dickerson and Mark Fuken."

Locality 4x

Architectonica pictum Philippi; living.
Conus ornatissimus K. Martin.
Cypræa.
Columbella bandongensis K. Martin.
Cerithidea cf. ornata Hinds; living.
Cerithium bandongensis K. Martin.
Delphinula??
Delphinula.
Eburna ambulacrum Sowerby; living.
Marginella.
Mitra bucciniformis K. Martin.
Mitra junghuhni K. Martin.
Mitra javana K. Martin.
Melania asperata.
Nassa costellifera A. Adams; living.
Nassa crenulata (Brugiere); living.
Operculum of Natica spadicea; living.
Phos roseatus Hinds; living.
Ranella tuberculata Broderip; living.
Rostellaria fusus Linnæus; living.
Rostellaria crispata Kiener; living.
Strombus, species a.
Turris marmorata; living.
Turris flavidula Lamarck; living.
Thais (or Ricinula) spectrum; living.
Terebra javana K. Martin.
Terebra bicincta K. Martin.
Trochus, species.
Arca ferruginea Reeve; living.
Corbula socialis K. Martin.
Chione chlorotica Philippi; living.
Glycimeris viteus Lamarck; living.

Pecten cf. pseudolima Sowerby; living.
Pecten cf. cristularis Adams & Reeve; living.
Pecten cf. radula Linnæus; living.
Pecten (Pleuronectia) pleuronecta Linnæus; living.
Placuna placenta Lamarck; living.
Solecurtus quoyi; living.
Spondylus, species.
Trochocyathus burnsi J. Haime (Cyclolites).

"Locality 5x, Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, west side of Ragay Gulf, Bahay River; 300 meters east of the mouth of Apad Creek in lignitic gray sandstone which was deposited in brackish water. Coll. Roy E. Dickerson" yielded the species listed below:

Cassidaria.
Conus loroisii Kiener; living.
Cerithium jenkinsi K. Martin.
Strombus?
Telescopium telescopium Linnæus; living.
Vicarya callosa Jenkins.
Arca tenebrica Reeve; living.
Chione ?
Ostrea, species.
Amber and petrified wood.

This fauna was made up largely of *Cerithium jenkinsi* K. Martin, *Vicarya callosa* Jenkins and *Ostrea,* species. The other forms are represented by only one or two specimens which were probably carried across the sand bar by small crabs which lived on the sands of the Vigo sea. The abundance of carbonaceous material and the occurrence of amber and petrified wood also indicate that conditions of deposition here differed from those of the previously described localities.

"Locality 9x, Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, on Dumalog Creek, about five miles northwest of San Narciso, three-quarters of a mile down stream from the Mulanay-San Narciso Trail in uppermost Vigo, just conformably below Canguinsa sandstone in black shale.

10/17/19. Colls. Roy E. Dickerson and Mark Fuken." The list of species is given below:

Locality 9x

Conus striatellus Jenkins.
Conus hardi K. Martin.
Nassa crenulata (Brugiere); living.
Strombus fusus K. Martin (probably Clavella).
Arca cf. cœlata Reeve; living.
Arca ferruginea Reeve; living.
Clementia hyalina Reeve=C. papyracea; living.
Dosinia cretacea Philippi; living.
Tellina.

This fauna though meager is not distinct in any way from faunas listed above. As Pratt[4] and Smith point out there is no evidence of any notable stratigraphic break here, and the stream in its meanderings so exposes the strata that exact observations are possible. Their tentative evidence of an unconformity between the Canguinsa and Vigo in Cambagaco ridge near the Vigo River is interpreted by the writer as a result of faulting.

"Locality 11x, Philippine Islands, Luzon, Tayabas Province, Bondoc Peninsula, on west bank of Sapa Yaknas, in soft yellow sandstone of Canguinsa age. 10/31/19. Coll. Roy E. Dickerson." The strata at this point dip west about 20° while the overlying Malumbang a few hundred feet west has a gentle dip of 2° to 3°, and at other places in this vicinity a notable unconformity separates these two formations. The fauna listed below is especially noteworthy as being composed of 85 to 90% living species. Here again, the stratigraphy is very satisfactory.

Locality 11x

Architectonica pictum (Philippi); living.
Cancellaria elegans Sowerby; living.
Cyprœa, species.

[4] Pratt, W. E., and Smith, W. D., Phil. Jour. Sci., Vol. VIII, 1913, Sec. A, No. 5, page 317.

Cerithidea near dohrni but detail differs.
Ficus reticulata (Lamarck); living.
Harpa articularis Lamarck; living.
Nassa thersites (Brugiere); living.
Nassa crenulata (Brugiere); living.
Nassa reussi K. Martin??; may be N. costellifera Adams.
Natica spadicea Reeve; living.
Natica cumingsiana Recluz; living.
Randella tuberculata Broderip; living.
Strombus swainsoni Reeve; living.
Terebra bicincta K. Martin.
Turris marmorata (Lamarck); living.

Pelecypoda

Cardita antiquata Linnæus; living.
Cardium attenuatum Sowerby; living.
Cardium unicolor Sowerby; living.
Clementia hyalina Philippi = C.papyracea; living.
Glycimeris viteus (Lamarck); living.
Glycimeris angulatus (Lamarck); living.
Ostrea.
Pecten pseudolima Sowerby; living.
Spisula, species.
Vermetus javanus K. Martin ???.

Anthozoa

Trochocyathus burnsi J. Haime ??

For comparison and summary purposes the fossils from these various localities have been combined in one list.

Partial list of Species from Vigo Group

	2×	3×	4×	5×	9×	11×	living
Architectonica pictum Philippi	+	+	+	..	..	+	+
Actæon, species	+	+	..	..	..	..	..
Bullaria	+	..	..	..	..	..	..
Cancellaria crenifera Sowerby	+	..	..	..	..	..	+
" elegans Sowerby	..	+	..	..	..	+	+
Cassidaria	..	..	..	+	..	..	..
Cerithium jenkinsi K. Martin	+	+	..	+	..	..	..
" monoliferum Kiener	+	+	..	..	..	..	+
" herklotsi K. Martin	+	+	..	..	..	..	..
" bandongensis K. Martin	..	..	+	..	..	..	..
Cerithidea (Pyrazus) cf. sulcatus Brugiere	..	+	..	..	..	..	+
" cf. ornata Hinds	..	..	..	..	..	..	+
" near dohrni ???	..	..	..	..	..	+	..
Conus ornatissimus K. Martin	+	+	+	..	..	..	..
" new species ??	+	+	..	..	..	..	..
" species	+	+	..	..	..	..	..
" lividus Hwass	+	..	..	..	..	..	+
" loroisii Kiener	..	..	..	+	..	..	+
" hardi K. Martin	..	..	..	..	+	..	..
" striatellus Jenkins	..	..	..	..	+	..	..
Columbella bandongensis K. Martin	..	..	+	..	..	..	..
Cyclonassa	+	..	..	..	..	..	..
Cypræa cf. tigris Linnæus	..	+	..	..	..	..	+
" species	..	..	+	..	..	+	..
Drillia	+	..	..	..	..	..	..
Delphinula ??	..	..	+	..	..	..	..
"	..	..	+	..	..	..	..
Distortio clathrata Lamarck	..	+	..	..	..	..	+
Eburna ambulacrum Sowerby	..	..	+	..	..	..	+
Ficus reticulata (Lamarck)	..	..	..	..	..	+	+
Haminea	+	..	..	..	..	..	..
Harpa articularis Lamarck	..	..	..	..	..	+	+
Mitra javana K. Martin	+	..	+	..	..	..	..
" cf. jenkinsi K. Martin	+	..	..	..	..	..	..
" junghuhni K. Martin	+	..	+	..	..	..	..
" bucciniformis K. Martin	..	..	+	..	..	..	..
Mangilia	+	..	..	..	..	..	..
Murex endivia Lamarck	..	+	..	..	..	..	+
Marginella	..	..	+	..	..	..	..
Melania asperata	..	+	+	..	..	..	+
Nassa crenulata	+	+	+	..	+	+	+
" dispar Adams	+	+	..	..	..	..	+
" gemmulata (Lamarck)	+	..	..	..	..	..	+
" globosa minor	+	+	..	..	..	..	+
" thersites immersa Carpenter	+	+	..	..	..	..	+
" thersites leptospira (Brugiere)	+	+	..	..	..	+	+
" quadrasi Hidalgo	+	+	..	..	..	..	+
" canaliculata Lamarck	..	+	..	..	..	..	+
" costellifera A. Adams	..	..	+	..	..	..	+
" reussi K. Martin (may = N. costellifera)	..	..	..	..	..	+	+

Partial List of Species—Continued.

	2×	3×	4×	5×	9×	11×	living
Natica albumen Lamarck	..	+	..	..	..	..	+
" ?	+	..	..	..	..	..	..
" spadicea Reeve	+	+	..	..	..	+	+
" mamilla Lamarck	+	+	..	..	..	..	+
" lacernula d'Orbigny	..	+	..	..	..	..	+
" cummingsiana Recluz	..	..	..	..	..	+	+
Nerita funiculata Reeve	+	..	..	..	..	..	..
Olivella	+	+	..	..	..	..	..
Phos	+	+	..	..	..	..	..
Ranella	+	..	..	..	..	..	..
Ranella subgranulosa Beck	+	..	..	..	..	..	+
" tuberculata Broderip	+	+	+	..	..	+	+
Rostellaria ficus	..	+	+	..	..	..	+
" crispata Kiener	..	+	+	..	..	..	+
Strombus canarium Linnæus	+	+	..	..	..	..	+
" species a	..	+	+	..	..	..	..
" species b	..	+	..	..	..	..	..
" swainsoni Reeve	+	..	..	..	..	+	+
" ?	..	..	..	+	..	..	..
Turris (Surcula) flavidus Lamarck	+	+	+	..	..	..	+
" garnonsi Reeve	+	+	+	..	..	..	+
" deshayesi (Doumet)	+	+	..	..	..	..	+
" carinata woodwardi K. Martin	+	+	..	..	..	..	+
" coronifera (K. Martin)	..	+	..	..	..	..	..
" marmora (Lamarck)	..	..	..	..	..	+	+
Thais (or Ricinula) spectrum	..	..	+	..	..	..	+
Terebra bicincta K. Martin	+	..	..	..	..	..	..
" javena K. Martin	+	..	+	..	..	..	..
"	+	+	..	..	..	..	..
Triton pfeifferianum Reeve	..	+	..	..	..	..	+
Trochus	..	..	+	..	..	..	..
Telescopium telescopium Linnæus	..	..	..	+	..	..	+
Vicarya callosa Jenkins	..	+	..	..	..	..	..

Partial List of Species from the Vigo Group.

Pelecypoda	2×	3×	4×	5×	9×	11×	living
Arca cornea Reeve	+	+	..	..	..	..	+
" ferruginea Reeve	..	+	..	..	+	..	+
" granosa Linnæus	..	+	..	..	..	..	+
" cf. cœlata Reeve	..	..	..	..	+	..	+
" tenebrica Reeve	..	..	..	+	..	..	+
Barbatia fusca (Brugiere)	..	+	..	..	..	..	+
Cardium	+	..	..	..	..	..	..
" attenuatum Sowerby	..	..	..	..	..	+	+
" unicolor Sowerby	..	..	..	..	..	+	+
Cardita antiquata Linnæus	..	..	..	..	..	+	+
Chione chlorotica Philippi	+	+	+	..	..	..	+
" ??	..	..	..	+	..	..	..
Corbula socialis K. Martin	+	+	+	..	..	..	..
Clementia hyalina Philippi = C. papyracea	..	..	..	..	+	+	+
Dosinia cf. lenticularis	..	..	..	..	..	..	+
" cretacea Philippi	..	..	..	..	..	..	+
Glycimeris viteus (Lamarck)	..	..	+	..	..	+	+
" angulatus (Lamarck)	..	..	..	..	..	+	+
Ostrea	+	+	..	..	..	+	..
Pecten (Pleuronectia) pleuronecta Linnæus	+	..	+	..	..	..	+
" cf. radula Linnæus	..	..	+	..	..	..	+
" cf. pseudolima Sowerby	..	..	+	..	..	..	+
" pseudolima Sowerby	..	..	..	..	..	+	..
" cf. cristularis Adams & Reeve	..	..	..	..	..	..	+
Placuna placenta	+	+	+	..	..	..	+
Psammobia cf. lessoni Blainville	+	..	..	..	..	..	..
Psammobia, species	..	+	..	..	..	..	..
Pinna, species	+	..	..	..	..	..	..
Paphia textrix Deshayes	+	..	..	..	..	..	+
Solen, species	+	..	..	..	..	..	..
Spisula, species	..	+	..	..	..	+	..
Solecurtus quoyi	..	..	+	..	..	..	+
Spondylus, species	..	..	+	..	..	..	..
Tellina	+	..	..	..	+	..	..
Tellina, species	..	+	..	..	..	..	..
Vermetus javanus ? K. Martin	..	..	..	..	..	+	..
Anthozoa							
Trochocyathus burnsi J. Haime	..	..	+	..	..	+	..
Coral	..	..	+	..	..	..	..
"	..	..	+	..	..	..	..

Age of the Vigo Group

In the foregoing list there are 87 forms which are specifically determined, and, of these, 66 are living species (75 per cent.) an astonishing number when the geologic history of the region yielding these forms is considered. In addition, the extinct forms are practically all common to the Upper Miocene of Java according to K. Martin[5].

Cerithium jenkinsi is from Martin's locality Z; *Cerithium herklotsi* and *Cerithium bandongensis* from his locality O; *Conus hardi* and *Conus striatellus,* locality O; *Columbella bandongensis,* locality O; *Mitra junghuhni* and *M. javana,* locality O; *M. jenkinsi,* locality K; *M. bucciniformis,* locality R; *Turris coronifer,* locality O; *Terebra javana* and *T. bicincta,* locality K; *Vicarya callosa,* localities O and P; *Vermetus javanus,* localities I and P. According to Martin, most of these forms are characteristic of the Upper Miocene of Java.

In a very excellent paper entitled "Concerning Tertiary Fossils in the Philippines" by Prof. Karl Martin, there is listed a series of faunas from the Cagayan Valley of northern Luzon which apparently belong to this same horizon. Concerning this series he gives the following discussion:

"Now, in reviewing Semper's collection, I was at once struck with *Vicarya callosa* Jenk., which is known from Java and is described in detail below; and this induced me to make a closer comparison between the fossils of the Philippines and those of the Indian Archipelago, whereby it at once became apparent that a whole series of species, especially of the Javanese Tertiary, is common to both regions. Thus far, indeed, I have been unable to make a complete study of Semper's collection, and for the time being it has little further interest, because statements as to stratigraphical position are entirely lacking and the equivalent deposits of neighboring regions are still very insufficiently known. After completion of my monograph on the fossils of Java, however, I hope to undertake a more thorough study of the Philippine fossils, and to supplement this preliminary communication."

Martin lists the following from Luzon:

1. Minanga; right bank of the Catalangan.

Fusus verbeeki Mart. ....M;P.
Tritonidea ventriosa Mart. ....M.
Murex brevispina Lam. ....M.(?);P;L.

[5] Martin, K., Tertiarschichten auf Java, p. 44-51, Leiden, 1880.

Murex pinnatus Wood ....M;L.
Ranella raninoides Mart....................M.
Rostellaria javana Mart....................M.
Natica mamilla Lam......................M;L.
Cardita decipiens Mart..................... P.
Venus squamosa Lam......................P;L.

2. Minanga; right bank of the Ilaroen.

Terebra jenkinsi Mart....................M.
Terebra bandongensis Mart. ....M.
Fusus verbeeki Mart. ....M;P.
Murex grooti Jenk.......................M.
Ranella gyrina Linn. ....L.
Rostellaria javana Mart. ....M.
Vicarya callosa Jenk. ....M.
Cardita decipiens Mart. ....P.

3. Right bank of the Ilaroen, 4 miles above Minanga.

Fusus verbeeki Mart......................M;P.
Murex brevispina Lam.....................M.(?);P;L.
Ranella raninoides Mart...................M.
Rostellaria javana Mart...................M.
Natica mamilla Lam......................M;L.

4. Left bank of the Ilaroen, 1¼ miles above Goroen.

Murex djarianensis Mart..................M.
Murex brevispina Lam.....................M.(?):P;L.
Murex microphyllus Lam..................M;L.
Murex grooti Jenk.......................M.
Ranella spinosa Lam......................M;L.
Potamides jenkinsi Mart..................P.
Natica mamilla Lam......................M;L.
Cardita decipiens Mart. .... P.

5. Left bank of the Ilaroen, 4 miles above Goroen.

Conus sinensis Sow.......................P;L.
Conus palabuanensis Mart. ....J.
Fusus verbeeki Mart. ....M;P.
Ranella gyrina Linn. ....L.

6. Foothills in front of Aringay.

Conus loroisii Kien. .... M;P;L.
Pleurotoma gendinganensis Mart. .... P.
Nassa verbeeki Mart. .... P.
Natica mamilla Lam. .... M;L.

7. Hills close to Aringay.

Pleurotoma carinata .... P;L.

8. Dicamui Brook.

Vicarya callosa Jenk. .... M.

9. Satput.

Cypræa smithi Mart. .... M.
Rostellaria javana Mart. .... M.

The appended initials indicate the occurrence of the species in the Tertiary of other parts of the Indian Archipelago, as well as among the fauna of the present day. Thus E denotes Eocene; M, Miocene; P, Pliocene; J, later Tertiary in general; Q, Quaternary; L, living species.

The fossils in Martin's list come from nine different localities and the largest number of species from any one locality is ten. The strata in the vicinity of Minanga are, according to Martin, essentially the same horizon and he says: "Judging from all these facts, the strata at Minanga are to be classed with the Upper Miocene bed which exists in Java in the locality denoted by Junghuhn by O, and at Selatjan on the Tjilongan." As was indicated above, many of the fossils from the Bondoc Peninsula are common to this locality O in Java, and the equivalence of the Upper Vigo beds with these Javan beds is evident. Upon the basis of Martin's work, the age of the Vigo beds is Upper Miocene.

Martin lists the distinctive foraminifera, *Cyloclypeus communis* Martin, from his (and Junghuhn's) localities K, L, O and P. *Orbitoides gigantea* Martin is from locality L, and *O. radiata* Martin is from locality K. These localities all represent about the same horizon in Java and it is important to note these forms here as they are regarded as excellent horizon determiners.

Dr. W. D. Smith[6], on the strength of the occurrence of *Cycloclypeus communis* K. Martin, and *Lepidocyclina richthofeni* Smith, refers the Canguinsa sandstone to the Middle or Lower Miocene. His exact statement is as follows:

"......The limestone from Mount Morabi (fossil locality 62) contains *Cycloclypeus communis* K. Martin, which represents the middle Miocene, and large lepidocyclinas some of which are 45 millimeters in diameter and 5 millimeters broad in the thickened central portion. *Lepidocyclina richthofeni* Smith was identified among these. This species has been referred by Douvillé to the lower Miocene.

"No definite age determinations can be made from the fossils in the Canguinsa sandstone proper. The fossils in the included limestone, however, are well known and have been used in correlation by various authorities. From their presence it is concluded that the Canguinsa sandstone should be placed in the middle Miocene, extending, perhaps, into the lower Miocene."

In a recent publication, "Notes on a Lepidocyclina-Limestone from Cebu," by Prof. H. Yabe[7], a full discussion of correlation of these equivalent beds in Cebu is given, and Smith's and Douvillé's[8] correlation tables are quoted.

It is noteworthy that beds under discussion are classified by Douvillé as Aquitanian. All who have studied the large foraminifera from the Philippine Islands agree that one of the characteristic genera is *Lepidocyclina*. Cushman[9] in a recent paper makes the following significant statement: "Because in general *Orbitoides*, with some modifications to be noted in a future paper, is Cretaceous, *Orthophragmina* Eocene, and *Lepidocyclina* Oligocene, much importance is attached to these organisms in the investigation of problems of geologic correlation."

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[6] Pratt, W. E., and Smith, W. D., Phil. Jour. Sci., Vol. VIII, 1913, No. 5, Sec. A, p. 330.

[7] Yabe, H., Science Reports, Tohoku Imperial University, 2nd Series, (Geol.), Vol. V, No. 2, 1919, p. 40.

[8] Douvillé, H., Les foraminifères dans le Tertiaire des Philippines. Phil. Jour. Sci., Vol. VI, 1911, No. 2, Sec. D, pp. 53-80.

[9] Cushman, J. A., Orbitoid Foraminifera of the Genus Orthophragmina from Georgia and Florida. U. S. G. S. Prof. Paper 108, 1918, p. 115.

From another point of view the age of the beds in question might depend upon the age determination of the overlying Malumbang formation. Concerning the age of this formation, Smith[10] states the case as follows:

"The most conclusive evidence as to the age of the Malumbang series is found in the Lower limestone, which, on the basis of the fossil *Lithothamnium ramosissimum* Reuss (fossil locality 25) may be assigned to the Miocene. The upper beds in the series are apparently as young as the Upper Miocene or the Pliocene. The formation is similar to the "étage marneux" which Verbeek assigns to the middle stage of the upper Tertiary for Java."

Concerning the range of this species, Prof. H. Yabe[11] notes the following:

"This reef building organism is very often cited from the limestone of the Oligocene and Miocene ages of the Indo-Pacific region, its occurrence being known from Japan, the Philippines, Borneo, Timor, Amboina, New Guinea and adjacent islands, New Hebrides, Victoria, the Christmas Islands, etc.

"In Japan, it is found not only in Lepidocyclina and Miogysina-limestones and similar and equivalent rocks of Formosa, Botel-tobako, the Riukiu-Islands and Ogasawara-jima, but also in 1. the Lepidocyclina and Miogypsina-limestones of the provinces of Sagami and Kai; 2. the Lithothamnium-limestones of Ogami-yama and Megami-yami near Sagara, province of Tōtōmi; 3. the Lithothamnium-limestone intercalated in an oil-bearing Tertiary complex of Echigo; 4. the Lithothamnium-limestone of Shiroiwa, Mukatsuka-mura, Otsugöri, pro. of Nagato."

It is evident from these references that this form has considerable range in the Miocene.

From all the evidence Canguinsa and Upper Vigo beds may be assigned to some stage of the Miocene, and the evidence of Lepidocyclina indicates a still greater age, the Oligocene.

[10] Op. cit., 327.

[11] Yabe, H., Notes on a *Carpenteria*-Limestone from B. N. Borneo. Science Reports, Tohoku Imperial University, 2nd Series (Geol.), Vol. V, No. 1, 1918, p. (28) 14.

Importance of Guide Fossils

Good guide fossils are far more difficult to select in connection with tropical Tertiary faunas of the Philippines than in the Californian Tertiary owing to the great predominance of recent mollusca. As will be seen from a study of the fauna cited above, most of the forms which are extinct were originally described from a correlative horizon in Java. Of these, the writer is inclined to think that *Cerithium jenkinsi, C. herklotsi, C. bandongensis; Mitra javana, M. jenkinsi, M. junghuhni, M. bucciniformis; Turris coronifer; Terebra bicincta, T. javana; Vicarya callosa; Vermetus javanus* will probably prove reliable guides among the mollusca. These species are all representatives of highly organized genera and their extinction during the post-Miocene time was probably due to their inability to obtain life conditions suited to their highly specialized needs.

Corals, echinoderms, and the more highly organized foraminifera will probably prove to be even better horizon determiners, but their comparative infrequence in strata of the Philippines will at times preclude their use. The writer has not yet attempted to identify the corals and the echinoderms in the collections made, but their value will no doubt prove to be great. It seems that their rate of evolution may have been greatly retarded, but much study will be required in this connection. For stratigraphic work in the tropics large and complete collections are necessary to obtain results of any value, as the geologic and paleontologic history is read, even with the best data available, with much difficulty. Much comparative material, both recent and fossil, should be accumulated as subspecific differences will be recognized only through comparative studies. These subspecific differences are exceedingly important for minute separation and discrimination of strata deposited under tropical conditions.

Factors Promoting Evolution of Pelecypods and Gastropods

The changes in conditions of environment of marine pelecypods and gastropods—in salinity, temperature, depth of water, character of the bottom, food, oceanic currents—determine the existence of individuals, and, in all probability, species also. Many marine forms are quite delicately adjusted to their environment and even slight changes may cause their extinction in certain localities. Of these conditions, change in temperature is probably the most important. The annual temperature range of the waters in the tropics is far less than similar ranges in the temperate zones. Likewise variations in salinity are probably less, as this is a secondary factor dependent in large part upon temperature. The influence of oceanic currents is intimately connected with temperature and salinity. Depth of bottom and the character of the bottom may be altered by changes in the volume of sediments brought into the ocean from the neighboring land and by epirogenic—continent building—movements which have caused a restriction or enlargement of a continental shelf. Epirogenic movements vitally affect food conditions of pelecypods and gastropods, for, if the continental shelf is greatly reduced by uplift, the feeding areas are thus reduced, and, if the competition among gastropods and pelecypods is too great, a species may rapidly become extinct. All of these changes are probably far less under tropical conditions than under temperate or arctic conditions.

Comparison of Life Conditions During Vigo Miocene Time With the Recent

The close relationship between the Vigo Miocene fauna of the Philippines and the recent fauna of these same waters, indicates that change in living conditions since the beginning of Miocene time has been but slight. Apparently change in temperature has not had any notable influence. It can be shown from general geological evidence that an archipelagic condition existed during Miocene, Pliocene and Pleistocene times. Salinity during the last half of the Tertiary and Recent has probably altered but little and this only locally. Oceanic currents and changes in character of ocean bottom were probably different during Vigo-Miocene time than during Malumbang-Pleistocene or Recent time, as is evidenced by the absence of reef building corals from the Vigo and the argillaceous and sandy character of the sediments of this group. A study of Vigo sedimentation indicates that an extensive land area stretched from north to south near the outer border of the continental shelf of the Philippines unbroken by straits like the San Bernardino of the present. Diorites, schists, serpentines and associated metamorphic and igneous rocks composed this land mass and the mud-laden, westerly-flowing streams deposited their loads in the Philippine inland sea of Miocene age. Judging from the coarse agglomeratic character of the basal Vigo beds in Leyte, high grade, torrential streams descended to a semi-arid lowland from a high, mountainous terrane to the east. The absence of many reef building corals from the Vigo fauna is probably due to the presence of muddy waters and the lack of strong currents, because the waters were quite warm enough for coralline growth, judging from the presence of many tropical species. From the character of both the sediments and fauna, the waters of the Vigo sea were not too deep for the existence of reef-building corals. During Malumbang time marine life conditions were very similar to those prevailing in the Philippines today, but the continental shelf was apparently far wider and the islands much smaller, since coralline limestone covered more extensive areas during the Pliocene than now. During the Pleistocene, the islands were outlined about as at present but many local changes took place during this time. Cebu for example was probably greatly restricted during the Pleistocene as well as during the Pliocene, and it was probably represented by several small islets then. Recent and Pleistocene faulting on a great scale seems to have largely controlled the physiography of this island. The northwestern peninsula of Leyte, 40 miles east, has not only a clear cut record in its terraced sides registering a series of uplifts, but an equally clear record of Recent or Pleistocene submergence on its west side. This last event is evidenced by a series of beautiful small bays, drowned valleys of small westward flowing antecedent streams. Such local movements did not seem to affect the species very materially on the whole. It is quite possible that some forms had to seek other quarters, but with such a great variety of neighborhoods from which to choose, every clam could find its proper mud flat and each snail its own dugout. The possible tendency of a species to have within itself the power to evolve into a higher form, or a form still better suited to its environment, is not apparently present in the case of the tropical pelecypods and gastropods, and the slow changes of fauna are apparently produced by slight changes in temperature, depth, salinity, and food. In other words, the "wonderful stability of protoplasm" seems to be exhibited in these marine tropical invertebrates except when environmental changes impress alterations upon this vital life substance.

Crowding of Species and the Recent Fauna of the Philippines

A seeming objection to the main thesis of this paper is found in connection with the great abundance of species in the marine waters surrounding the Philippine Islands. As was mentioned above, climatic zones were by no means as sharply differentiated during the early as during the later portion of the Tertiary. Practically all Recent tropical genera were initiated in the Eocene, and many of the species representing these genera had, during this period, an exceedingly wide geographic range, particularly as respects latitude. During this time tropical species flourished in high latitudes. To use a simple comparison, the tropical life "accordion" was extended to its greatest limit. The exact nature of the change which caused a separation of remarkable distinctness between the Oligocene faunas of the Pacific Coast of North America from the Eocene is not fully understood. It seems probable however that the time represented by unconformity between Oligocene and Eocene was long. The distribution of land masses on the earth was profoundly affected, and it seems quite probable that the climate during this ep-Oligocene time was decidedly cooler than in the Eocene or the Oligocene which followed. It seems quite probable that the life "accordion" was compressed and many species which ranged far to the north in Eocene time were compelled to seek the more genial climes of the tropic seas. When the faunas during the Oligocene again had a chance to expand into higher latitudes, they encountered new conditions of environment and were nearly all specifically changed. The Oligocene faunas of Oregon, Washington, and California are distinctly set off from the Miocene and similar changes may have taken place during ep-Miocene time. Again many of the species succeeded in making a strategic retreat. Even more pronounced were the "accordion"-like changes during the Pliocene, and during the Pleistocene "jig-time" was in vogue.

As was pointed out above, archipelagic conditions prevailed in the Philippines during the Tertiary, although the record for the Miocene is missing or extremely meager. An archipelago located in the tropics offers a great variety of habitat, and a new species entering such a region could on this account find suitable conditions for existence.

From Miocene to Recent in the tropics molluscan faunas have changed but little, and but slight specific alterations have occurred as well. Since a tropical or sub-tropical climate prevailed over California, Oregon, and Washington during upper Eocene time, the great geographic and stratigraphic ranges of certain species of Tejon (Upper Eocene) age is due to nearly uniform conditions and other factors mentioned. The great stratigraphic range of many Tejon Eocene species is probably due to uniformity in climate during long periods of time and slight faunal changes have greater significance in the Upper Eocene than corresponding changes in the Miocene, Pliocene, and Pleistocene time and these variations probably required a much longer time for their production as well. Uniformity in oceanic temperature enabled many species to range far to the north, and, in fact, far west of California to the Eocene of Japan where *Perissolax blakei, Pholadomya nasuta* or their near relatives occur[12].

The Eocene time then must not be measured by the same faunal "yardstick" as Pliocene and Miocene time, but a much finer scale is required. It is the writer's opinion, based upon such considerations, that Eocene time is far longer than any of the other divisions of the Tertiary.

Summary

The tentative conclusion of the writer is that in the study of Tertiary faunas of the tropics, a different percentage scale must be used. For the later Tertiary, Miocene, Pliocene, and Pleistocene the percentages which apply in the temperate re-

[12] Yokoyama, M., Some Tertiary Fossils from the Miike Coal-field. Journal of the College of Science, Imperial University of Tokyo, Vol. XXVII, 1911, Art. 20.

gions to the Pliocene are roughly adaptable to the Miocene, and similarly the percentages which apply in the temperate regions to the Pleistocene are apparently those of the Pliocene of the tropics. The reasons for this apparent lack of faunal differentiation during the Tertiary in the tropics are those due to uniformity of temperature, salinity, food, and other life essentials. From another viewpoint the rate of evolution of Gastropoda and Pelecypoda in the tropics during the Tertiary was far less than during this same time in the more rigorous environs of the temperate zones. The tropical or sub-tropical faunas of the Eocene of the Pacific Coast of North America exhibit but slight differences compared to the faunas of Miocene and Pliocene age of this same region, and the writer ascribes this to uniformity of life conditions which prevailed during Eocene time. The amount of faunal change must not be used as a measure of time in the whole of the Tertiary, but differently marked scales are necessary for measurement in tropical and sub-tropical faunas of the Eocene and Oligocene than for the Miocene, Pliocene, and Pleistocene. It is particularly noteworthy that the Japanese paleontologists are now searching for comparisons with the Pacific Coast of North America and Australia rather than with Europe. In other words, many problems of the tropical Orient will be solved only when conditions on both sides of the Pacific become better known.